Vol 15 (2), 2026, 132-137 DOI: 10.23960/jppk.v15.i2.15211
Jurnal Pendidikan dan Pembelajaran Kimia
e-ISSN: 2714-9595| p-ISSN 2302-1772
http://jurnal.fkip.unila.ac.id/index.php/JPK/index

Development of an Interactive Problem-Based Learning E-Module to Improve Higher-Level Thinking Abilities in Thermochemistry

Winda Sari Luciana Marpaung*, Jamalum Purba

Depertement Chemistry Education, Faculty Of Mathematics and Natural Science, Medan State University
Jl. Willem Iskandar, Pasar V, Medan, Indonesia
.
*Correspondinge-mail: windamarpaung068@gmail.com

Received: April 20th, 2026 Accepted: July 10th, 2026 Online Published: August 11th, 2026

Abstract: Development of An Interactive Problem-Based Learning E-Module to Improve Higher-Level Thinking Abilities in Thermochemistry. 21st-century education demands the development of students' Higher Order Thinking Skills (HOTS). However, the abstract and calculation-heavy nature of the eleventh-grade thermochemistry material makes it difficult for students to comprehend when relying solely on conventional textbooks. Furthermore, the learning process in schools is still heavily dominated by teacher-centered lecture methods. As a solution, an interactive e-module was developed by integrating multimedia and the Problem-Based Learning (PBL) model to stimulate analytical thinking and problem-solving skills. This study is a Research and Development (R&D) project using the 4D development model, which consists of the Define, Design, Develop, and Disseminate stages. The instrument trial subjects involved 35 eleventh-grade students in class XI C at SMA Negeri 17 Medan. The feasibility of the e-module was evaluated through validation by material and media expert lecturers. The validation results showed an average score of 93.93% from the material experts and 92.15% from the media experts, classifying the e-module as highly valid. Additionally, the e-module received a highly positive response from students, achieving a practicality percentage of 88.17%. The use of the interactive PBL-based e-module is proven effective in improving students' Higher Order Thinking Skills. This is demonstrated by the increase in the average score from the pretest (28.19) to the posttest (82.09), yielding an N-Gain score of 0.74, which falls into the medium category.

Keywords: E-modul, Problem Based Learning, Higher Order Thinking Skills, Thermochemistry.

Abstrak: Development of An Interactive Problem-Based Learning E-Module to Improve Higher-Level Thinking Abilities in Thermochemistry. *Pendidikan abad ke-21 menuntut pengembangan Keterampilan Berpikir Tingkat Tinggi (Higher Order Thinking Skills atau HOTS) siswa. Namun, sifat materi termokimia kelas XI yang abstrak dan sarat perhitungan menyulitkan siswa untuk memahaminya jika hanya mengandalkan buku teks konvensional. Selain itu, proses pembelajaran di sekolah masih sangat didominasi oleh metode ceramah yang berpusat pada guru. Sebagai solusi, sebuah e-modul interaktif dikembangkan dengan mengintegrasikan multimedia dan model Problem-Based Learning (PBL) untuk merangsang kemampuan berpikir analitis dan pemecahan masalah. Penelitian ini merupakan proyek Penelitian dan Pengembangan (Research and Development atau R&D) yang menggunakan model pengembangan 4D, yang terdiri dari tahapan Define (Pendefinisian), Design (Perancangan), Develop (Pengembangan), dan *Disseminate* (Penyebarluasan). Subjek uji coba instrumen melibatkan 35 siswa kelas XI C di SMA Negeri 17 Medan. Kelayakan e-modul dievaluasi melalui validasi oleh dosen ahli materi dan ahli media. Hasil validasi menunjukkan skor rata-rata 93,93% dari ahli materi dan 92,15% dari ahli media, yang mengklasifikasikan e-modul tersebut sebagai sangat valid. Selain itu, e-modul ini mendapat respons yang sangat positif dari siswa,*

*dengan tingkat kepraktisan mencapai 88,17%. Penggunaan e-modul interaktif berbasis PBL terbukti efektif dalam meningkatkan Keterampilan Berpikir Tingkat Tinggi siswa. Hal ini ditunjukkan oleh peningkatan skor rata-rata dari *pretest* (28,19) ke posttest (82,09), yang menghasilkan skor N-Gain sebesar 0,74, yang termasuk dalam kategori sedang.*

Kata kunci: *E-modul, Problem Based Learning, Higher Order Thinking Skills, Thermochemistry*

▪ INTRODUCTION

21st-century education requires students to possess Higher Order Thinking Skills (HOTS), which encompass the abilities to analyze, evaluate, and create. This aligns closely with both the *Kurikulum Merdeka* (Independent Curriculum) and the 2013 Curriculum, which emphasize the importance of developing critical, creative, collaborative, and communicative thinking skills within the school learning process. As a science subject, chemistry plays a vital role in fostering these skills, particularly because many chemical concepts relate to real-world phenomena in daily life. Despite this importance, many students still struggle to learn chemistry—especially topics like thermochemistry, which are abstract and calculation-heavy. These difficulties are compounded by instructional processes that remain dominated by conventional methods focused on information delivery, thereby failing to emphasize the development of HOTS. Furthermore, the teaching materials employed by teachers often consist of standard textbooks or printed modules that lack interactivity, resulting in low student engagement. To address the issue of teaching material availability, the development of interactive e-modules is believed to enhance students' HOTS, as these offer numerous advantages over conventional printed modules. E-modules provide multimedia integration, interactivity, and learning flexibility, enabling students to grasp abstract concepts through animations, simulations, and visualizations. The use of e-modules also fosters learner autonomy, allowing students greater freedom to explore the subject matter. To maximize the effectiveness of e-module-based learning in cultivating HOTS, an appropriate instructional framework such as the Problem-Based Learning (PBL) model is required to actively engage students. PBL is an instructional model that presents relevant, authentic problems to facilitate student problem-solving. Integrating open-ended problems characteristic of PBL into e-modules directly guides students to analyze, evaluate, and formulate creative solutions through contextual problem-solving activities. Thus, the development of an interactive PBL-based e-module can serve as an innovative solution to enhance higher-order thinking skills and the quality of chemistry learning, aligning with 21st-century demands.

▪ METHOD

This study employs the Research and Development (R&D) method. The development model applied is the 4D model—adapted from Thiagarajan—which comprises four main stages: Define, Design, Develop, and Disseminate. The primary objective of this research is to produce a valid, practical, and effective interactive e-module based on Problem-Based Learning (PBL) for the topic of Thermochemistry, aimed at enhancing the Higher-Order Thinking Skills (HOTS) of high school students. The implementation steps follow the four operational stages of the 4D model: Define Stage: Conducted to establish objective requirements and parameters regarding the

learning material being developed. Design Stage: The phase for creating an initial draft or prototype of the e-module based on the needs analysis. Activities include: Standardized Test Preparation (designing the test blueprint and HOTS-based assessment instruments to measure students' higher-order thinking capabilities) and Media Selection (determining supporting digital platforms: Canva for visual design, Microsoft Word for content drafting, Google Forms for quizzes/evaluations, and Flip PDF Professional for converting the document into an interactive flipbook format). Develop Stage: Aimed at producing a valid and viable final e-module product. Disseminate Stage: The validated e-module product is implemented in a sample class.

▪ RESULT AND DISCUSSION

The development of this interactive e-module based on Problem-Based Learning (PBL) for Thermochemistry was evaluated across three main aspects: feasibility (validity), practicality, and effectiveness. Feasibility of the E-Module (Expert Validation) Based on expert assessments, the e-module draft was declared highly feasible for implementation. The material expert validation, which covered content, presentation, and contextual feasibility, achieved an average score of 93.93%, categorizing it as "Highly Valid". Meanwhile, the media expert validation assessing graphics and language elements obtained an average score of 92.15% ("Highly Valid"). This high level of feasibility aligns with a previous study by Elfiza and Hardeli (2024) on the validation of a PBL-based thermochemistry e-module for the Merdeka Curriculum, which emphasizes that integrating PBL syntax into thermochemistry topics meets current digital teaching material standards. This is further supported by Dewi and Mercuriani (2024), who found that packaging abstract material into a problem-based digital device is proven to facilitate students' independent conceptual understanding.

Practicality of the E-Module (Student Responses) A limited field trial conducted in class XI C at SMA Negeri 17 Medan indicated that the e-module is highly practical for use in learning. The student response questionnaire yielded an average percentage of 88.17%, falling into the "Highly Positive" category. This practicality is driven by interactive multimedia components, such as videos, interactive quizzes, flipbook features, and QR codes. This finding is linear with the research results of Lestari and Sabani (2025), which state that visual readability and ease of navigation in PBL-based e-modules massively increase students' independent learning motivation. Theoretically, this visual interactivity minimizes student verbalism in understanding abstract scientific phenomena (Saralee et al., 2024).

Effectiveness of the E-Module (HOTS Improvement) The effectiveness of the e-module was measured through the improvement of students' Higher Order Thinking Skills (HOTS) using Normalized Gain (N-Gain) analysis. The results showed a significant increase in learning outcomes, where the students' average score surged from 28.19 during the pre-test to 82.09 in the post-test. Through the Hake index calculation, an N-Gain value of 0.74 was obtained, which is classified under the "High" category.

This improvement in HOTS capabilities (C4 to C6 aspects) confirms the meta-analysis results by Alvionita (2025) and Fitri and Mufit (2024), which concluded that the PBL model exerts a strong positive influence on cognitive learning outcomes and students' critical thinking skills in chemistry. The characteristics of thermochemistry material, which involve energy calculations and abstract concepts, can be well internalized because the PBL stages or syntax (from problem orientation to evaluation) train students' logical reasoning in a structured manner, similar to the findings of Zhafirah

et al. (2025) and Mayanty dkk. (2022). Although there are technical challenges, such as variations in internet network stability and the diverse initial abilities of students in heterogeneous classrooms, as mapped out by Viehmann et al. (2024), cumulatively, this PBL-based interactive e-module is proven to be valid, practical, and effective as an innovative medium to boost students' higher-order thinking skills in Thermochemistry.

▪ CONCLUSION

The development of an interactive e-module based on problem-based learning (PBL) has proven highly valid and effective in improving students' higher-order thinking skills in thermochemistry. Validation by material and media experts showed a very high average feasibility score, while student responses were also very positive towards the use of this e-module. The impact of the e-module implementation was seen in a significant increase between pretest and posttest results, although the N-gain score was still in the moderate category. The main strengths of this e-module lie in its interactivity, use of multimedia, flexibility of access, and integration of contextual questions that require students to think critically, creatively, and evaluatively according to the HOTS (Higher Order Thinking Skills) domain. Teacher support as a facilitator and the use of supporting applications such as Canva, Google Forms, and Flip PDF Professional also helped strengthen the in-depth and independent learning experience. These findings align with literature that confirms the superiority of PBL and digital teaching materials in promoting higher-order thinking skills, both in chemistry and other fields. However, several challenges such as gaps in students' initial abilities, technical constraints, and the need for independent learning adaptations require attention to optimize future implementation. This research confirms that the integration of PBL-based interactive e-modules is worthy of being an effective alternative in 21st-century learning, supports curriculum achievements, and can be replicated for other materials and levels with further development.

▪ REFERENCES

Alvionita, S. (2025). Meta-analysis of the effect of Problem-Based Learning (PBL) on chemistry learning outcomes. BALANGA: Jurnal Pendidikan Teknologi dan Kejuruan, 13(1).

Batamuliza, J., Habinshuti, G., & Nkurunziza, J. B. (2024). Exploring lower secondary school teachers' perceptions of integrating simulations into chemistry instruction. In Frontiers in Education (Vol. 9, p. 1484495). Frontiers Media SA.

Dewi, R., & Mercuriani, I. S. (2024). Development of E-Module in Problem Based Learning (PBL) on biotechnology material to increase learning independence and understanding of concepts for class XII SMA students. Jurnal Penelitian Pendidikan IPA, 10(9), 6552–6563.

Elfiza, R., & Hardeli, H. (2024). Validasi e-modul materi termokimia berbasis PBL untuk menunjang pembelajaran Kurikulum Merdeka Fase F kelas XI SMA/MA. MASALIQ, 4(4), 870–880.

Fitri, A. M., & Mufit, F. (2024). Meta-analysis of the effect of the Problem-Based Learning model on critical thinking skills. Journal of Learning and Technology in Physics, 2(1).

Gufran, G., & Mataya, I. (2020). Pemanfaatan E-Modul Berbasis Smartphone Sebagai Media Literasi Masyakarat. JISIP (Jurnal Ilmu Sosial Dan Pendidikan), 4(2). https://doi.org/10.58258/jisip.v4i2.1060

Lestari, Y., & Sabani, S. (2025). Pengembangan e-modul berbasis Problem Based Learning (PBL) pada materi fluida statis di SMA Swasta Imelda Medan. INPAFI (Inovasi Pembelajaran Fisika), 13(1).

Malik, A., Rosidin, U., & Ertikanto, C. (2018). Pengembangan Instrumen Asesmen HOTS Fisika SMA Menggunakan Model Inkuiri Terbimbing. In Jurnal Lentera Pendidikan Pusat Penelitian LPPM UM METRO (Vol. 3, Issue 1).

Mayanty, S., Astra, I. M., & Rustana, C. E. (2022). Efektivitas penerapan e-modul berbasis Problem Based Learning (PBL) terhadap keterampilan proses sains siswa SMA. Journal of Physics Education, 2(2).

Mawarni, J., & Hendriyani, Y. (2021). Pengembangan Media Pembelajaran E Modul Interaktif Pada Matakuliah Pemrograman Visual Dengan Metode Pengembangan Addie. JAVIT : Jurnal Vokasi Informatika, 1–8. https://doi.org/10.24036/javit.v1i3.67

Mutmainnah, M., Aunurrahman, A., & Warneri, W. (2021). Efektivitas Penggunaan E-Modul Terhadap Hasil Belajar Kognitif Pada Materi Sistem Pencernaan Manusia Di Madrasah Tsanawiyah. Jurnal Basicedu, 5(3), 1625–1631. https://doi.org/10.31004/basicedu.v5i3.952

Ningrum, I. P., & Marsinun, R. (2022). Penerapan Model Pembelajaran Problem Based Learning untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa. Jurnal Basicedu, 6(5), 8205-8214. doi:https://doi.org/10.31004/basicedu.v6i5.3784

Nisa, I., Ainia, N., & Nur, D. M. M. (2025). Pemanfaatan Aplikasi Canva dalam Penyusunan Media Pembelajaran Berbasis Teknologi. Jurnal Ilmiah Perkembangan Pendidikan Dan Pembelajaran, 02(02), 67–77.

Purba, J., Sutiani, A., Panggabean, F. T. M., Silitonga, P. M., & Dibyantini, R. E. (2023). Development of e-module organic chemistry learning case method-based to improve student HOTS. The 9th Annual International Seminar on Trends in Science and Science Education (AISTSSE) 2022, 0, 321–327. https://doi.org/10.2478/9788367405195-044

Putra, I. M. C. W., Astawan, I. G., & Antara, P. A. (2022). Lembar Kerja Peserta Didik Digital Berbasis PBL pada Muatan IPA Sekolah Dasar. Mimbar PGSD Undiksha, 10(1), 155- 163.

Putra, A. W., Harizon, & Haryanto. (2025). Development of chemistry e-modules based on Problem Based Learning (PBL) on colloidal material at SMAN 2 Muaro Jambi. Jurnal Pengabdian Masyarakat dan Riset Pendidikan, 4(1), 1333–1338.

Ramadanti, F., Mutaqin, A., & Hendrayana, A. (2021). Pengembangan E-Modul Matematika Berbasis PBL (Problem Based Learning) pada Materi Penyajian Data untuk Siswa SMP. Jurnal Cendekia : Jurnal Pendidikan Matematika, 5(3), 2733–2745. https://doi.org/10.31004/cendekia.v5i3.759

Saralee, A., Fitria, Y., Sukma, E., & Hidayati, A. (2024a). the Development of Module IPAS Based on Problem Based Learning Assisted with Articulate Applications to Improve Students Think Critically. Jurnal Penelitian Pendidikan IPA, 10(4), 2032–2040. https://doi.org/10.29303/jppipa.v10i4.7014

Viehmann, C., Fernández Cárdenas, J. M., & Reynaga Peña, C. G. (2024). The use of socioscientific issues in science lessons: A scoping review. Sustainability, 16(14), 5827.

Yaumi, Y. & Taufikurohmah, T. 2019. Development of science learning material with socio scientific issues (SSI) on climate change materials to improve science literacy of junior high school student. Jurnal Penelitian Pendidikan IPA, 4(2):56-63. https://doi. org/10.26740/jppipa.v4n2.p56-63.

Yulianto, D., Junaedi, Y., Juniawan, E. A., & Anwar, S. (2024). Kemampuan Berpikir Tingkat Tinggi Siswa SMP melalui Pendekatan Matematika Realistik dengan Model PBL dan CTL Berbasis Project-Based Learning pada Penyelesaian Soal AKM di Kabupaten Lebak Banten. Teorema: Teori dan Riset Matematika, 9(1),57-76.

Zhafirah, T., Erna, M., & Rery, R. U. (2025). Development of e-module based on Problem Based Learning (PBL) in hydrocarbon material. AL-ISHLAH: Jurnal Pendidikan.

Zamsiswaya, Z., Sawaluddin, S., & Sihombing, B. (2024). Model Pengembangan 4D (Define , Design , Develop , dan Disseminate) dalam Pembelajaran Pendidikan Islam. Journal of Islamic Education El Madani, 4(1), 11–19